DArkSIDE-50

performance and results from the first atmospheric argon run

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DArKSIDE STRATEGY

Multi-stage program searching for dark matter direct interactions in low-background detectors deployed at Gran Sasso underground lab.

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Multi-stage program searching for dark matter direct interactions in low-background detectors deployed at Gran Sasso underground lab.

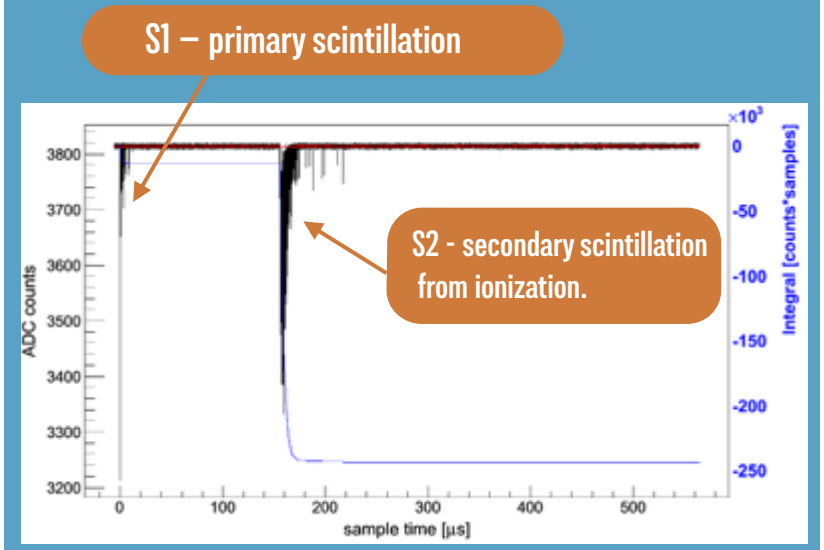
Two-Phase Time Projection Chamber

- *Detect scintillation and ionization channels (S1 and S2).*
- *Provides 3 tools for identifying nuclear recoils (NR) among the overwhelming electron recoil (ER) background.*
  - ✦ *Pulse Shape Discrimination (based on S1)*
  - ✦ *Ratio of ionization/scintillation (based on S1 and S2)*
  - ✦ *3D reconstruction (based on S2)*

Low-Radioactivity Underground Argon (UAr)

- *<6.5 mBq/kg of ^{39}Ar, <1/154 of atmospheric argon (AAr)*

ARGON TPC



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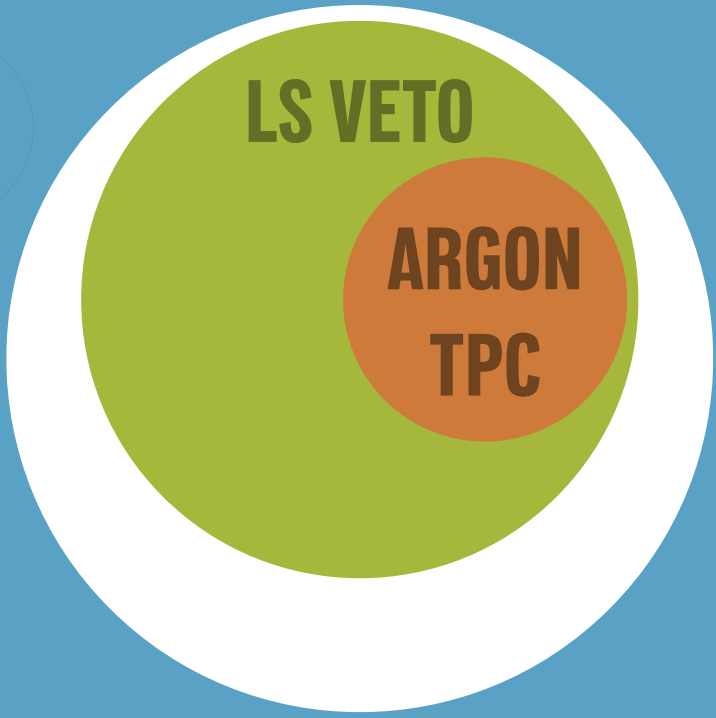

Boron-loaded organic liquid scintillator detector

- *30 tonnes: 50% PC and 50% TMB*
- *Readout by 110 low-radioactivity PMTs*

Passive shield against neutrons and gammas

Efficient tagging of neutrons through n-capture

- *Emitted gamma+alpha (94%) and alpha (6%)*

Designed to host DS-50 and DS-G2

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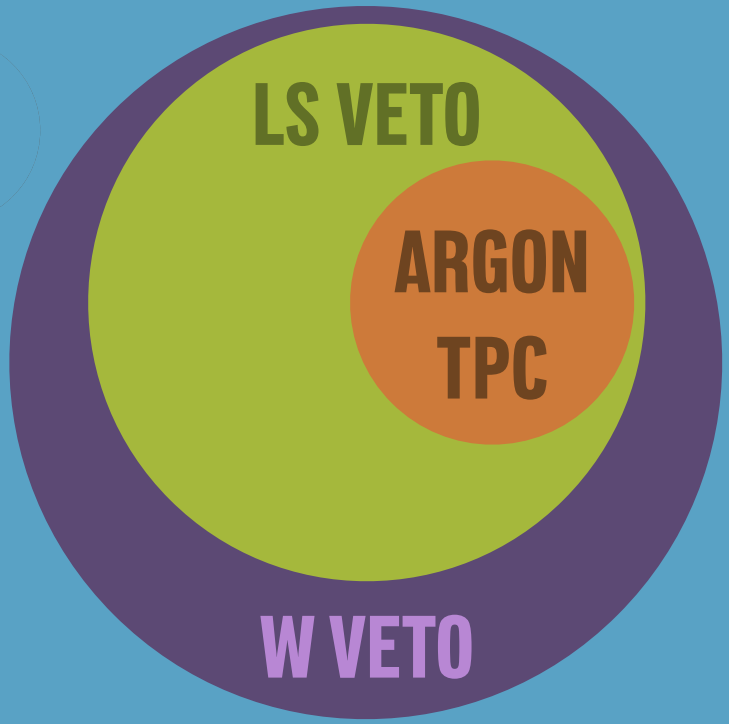


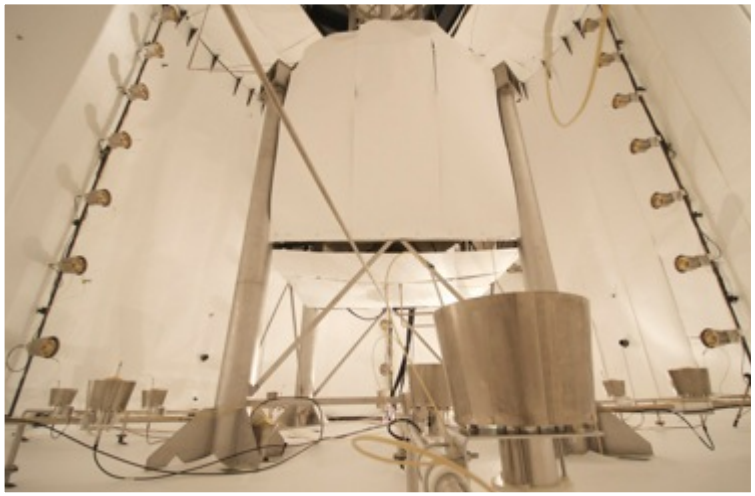
Water Cherenkov Muon detector

- *1000 tonnes of pure water*
- *Readout by 80 PMTs*

Passive shield against neutrons and gammas

Detects muons to tag cosmogenic-neutrons

Designed to host DS-50 and DS-G2



DArKSIDE-50: STATUS & PROGRAM

First WIMP-sensitive detector of the DarkSide family.

TPC active mass of about 50 kg of argon.

OCT 2013: LAr TPC, NEUTRON VETO and MUON VETO commissioned

- TPC filled with Atmospheric Argon (AAr).
- Operating since then with all three detectors active, as intended for dark matter search

DArKSIDE-50: STATUS & PROGRAM

First WIMP-sensitive detector of the DarkSide family.

TPC active mass of about 50 kg of argon.

NOV-JAN 2014: DAQ, DATA HANDLING and PROCESSING improvements while taking AAr data

Unique opportunity to collect large statistics of ER to study rejection performance for DS-50 and DS-G2.

DArKSIDE-50: STATUS & PROGRAM

First WIMP-sensitive detector of the DarkSide family.
TPC active mass of about 50 kg of argon.

UP to 20th of FEB 2014: collected 6.3 live days of AAr.

- Results presented today refer to 6.3 live days (278 kg · day fiducial).
- Collected as many ^{39}Ar events as expected in 2.6 year of UAr DS-50 run.*
- Studied the rejection of the expected dominant ER background with UAr.
- Current analysis does not exploit S2/S1 and x-y reconstruction, requires additional in-situ calibrations.
- Electron Recoil background fully suppressed even WITHOUT S2/S1 and x-y reconstruction but using S2 - S1 timing for z determination and rejection of multiple interactions.

* if ^{39}Ar in UAr is assumed at the level of the present **upper limit** (6.5mBq/kg)

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TPC active mass of about 50 kg of argon.

APR-MAY 2014: Exchange of TMB in the LS VETO

- Observed high ^{14}C rate in the LS VETO due to TMB
- Developed a LOOP procedure to separate PC from TMB using Borexino distillation plant*
- Identified a new batch of TMB with low ^{14}C content
- Repeat procedure (used the first time) for mixing new TMB with PC

*No need to empty WT detector or TPC

DArKSIDE-50: STATUS & PROGRAM

First WIMP-sensitive detector of the DarkSide family.

TPC active mass of about 50 kg of argon.

MAY-JUN 2014: increase ^{39}Ar statistics and perform in-situ calibrations

Considering injection of ^{39}Ar in recirculation to increase the rate of ^{39}Ar decays (source already available)

DArKSIDE-50: STATUS & PROGRAM

First WIMP-sensitive detector of the DarkSide family.

TPC active mass of about 50 kg of argon.

JUN 2014: Switch to Underground Argon for 3-year dark matter search

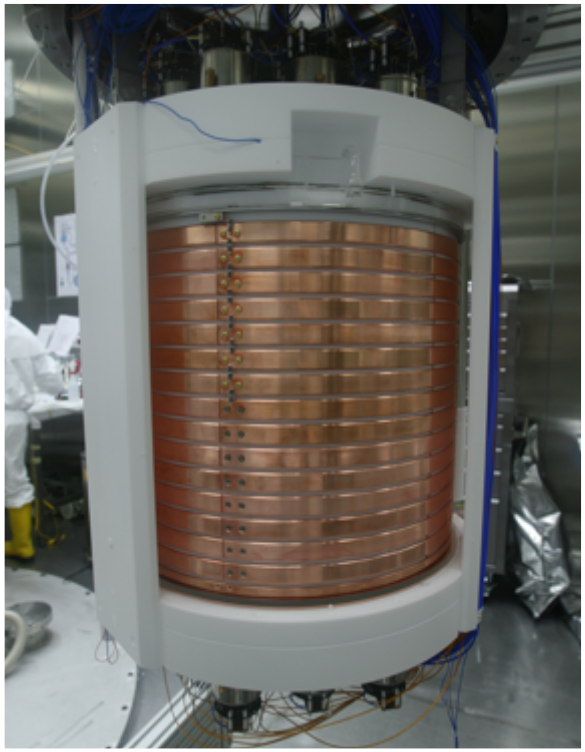
LAr TPC: COMMISSIONING

- PMTs: all 38 Hamamatsu R11065 PMTs are operating steadily since October 2013. PMT Gain fluctuations with time are within 1-2%. Flasher issue fully fixed by using cold amplifiers on PMT voltage dividers and operating PMTs at lower HV and gain.

- HHV: Operating the TPC at nominal electric fields (E_d=200 V/cm, E_{ext}=2.8 kV/cm). HHV has not shown any instability since commissioning (Oct 2013).

- Ar purity*: An electron-lifetime larger than 5 ms has been achieved and maintained for a few months. This is to be compared to the maximum drift time of 370 us.

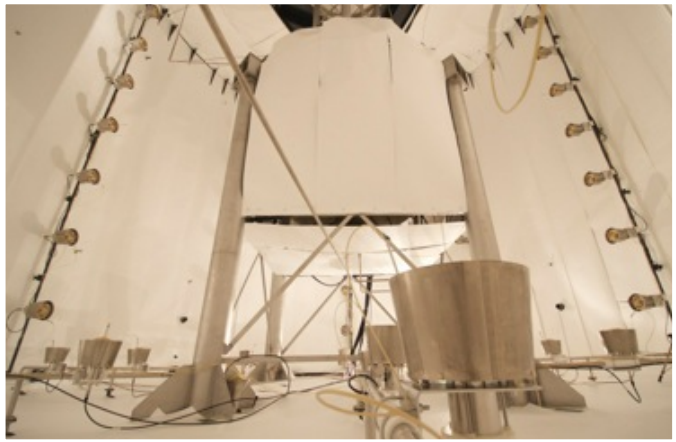
- Cryogenics*: The cryogenic system is highly stable and with low power consumptions.



* See *"The DarkSide-50 detector and its cryogenics"* from Y.Suvorov on Friday

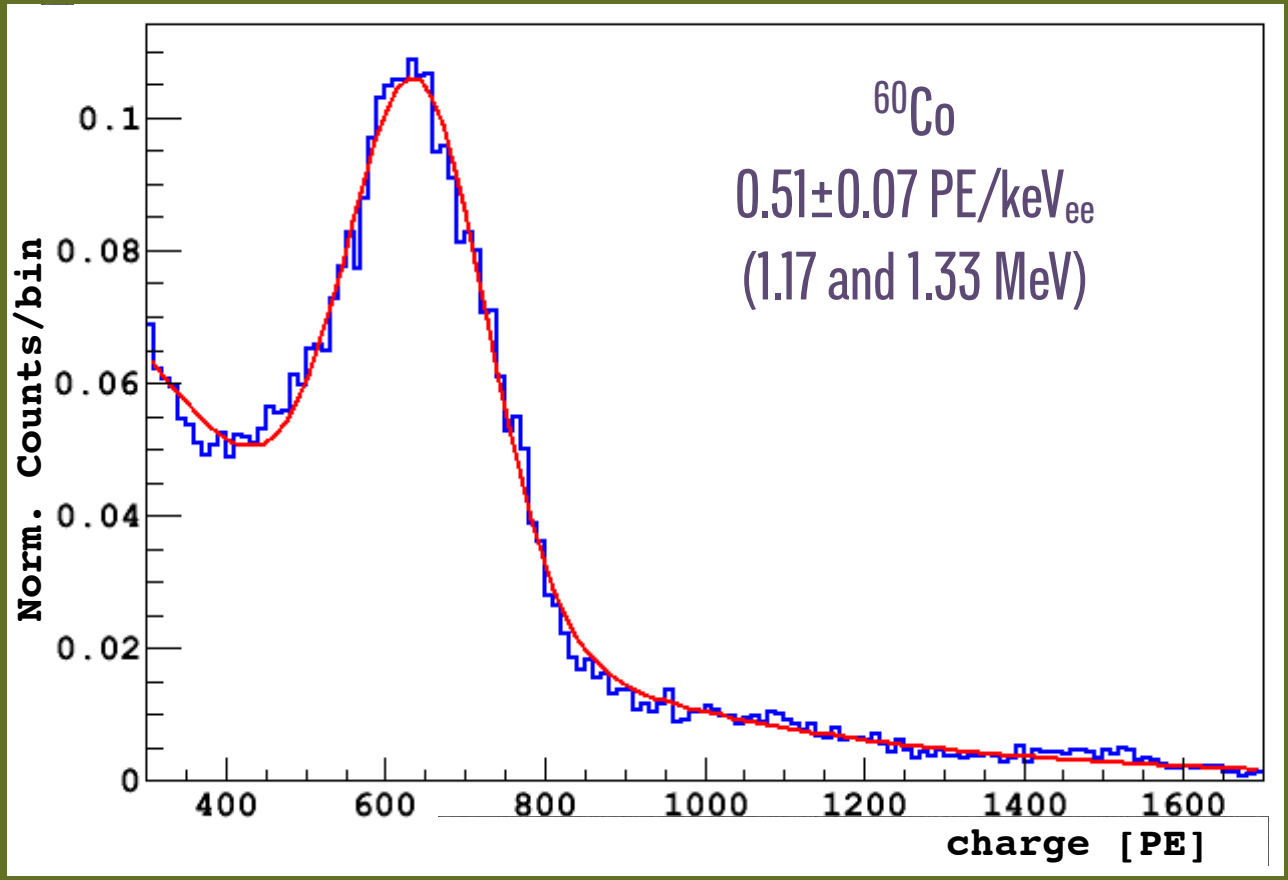
OUTER DETECTORS: COMMISSIONING

- Light Yield: liquid scintillator VETO LY of about 0.5 PE/keV$_{ee}$, satisfactory for VETO requirements.



OUTER DETECTORS: COMMISSIONING

- Light Yield: liquid
  satisfactory for VE



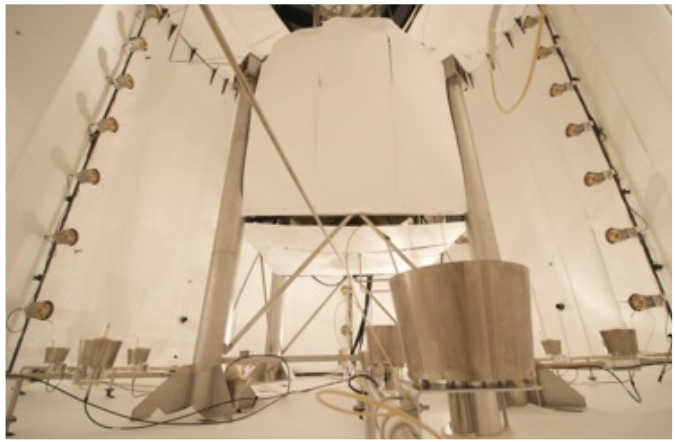
Fit spectral features of the scintillation spectrum detected in the LS VETO.

- *Gammas from ^{60}Co (known to be present in SS of the TPC cryostat)*
- *Confirmed by ^{14}C and ^{208}Tl fits as well.*

OUTER DETECTORS: COMMISSIONING

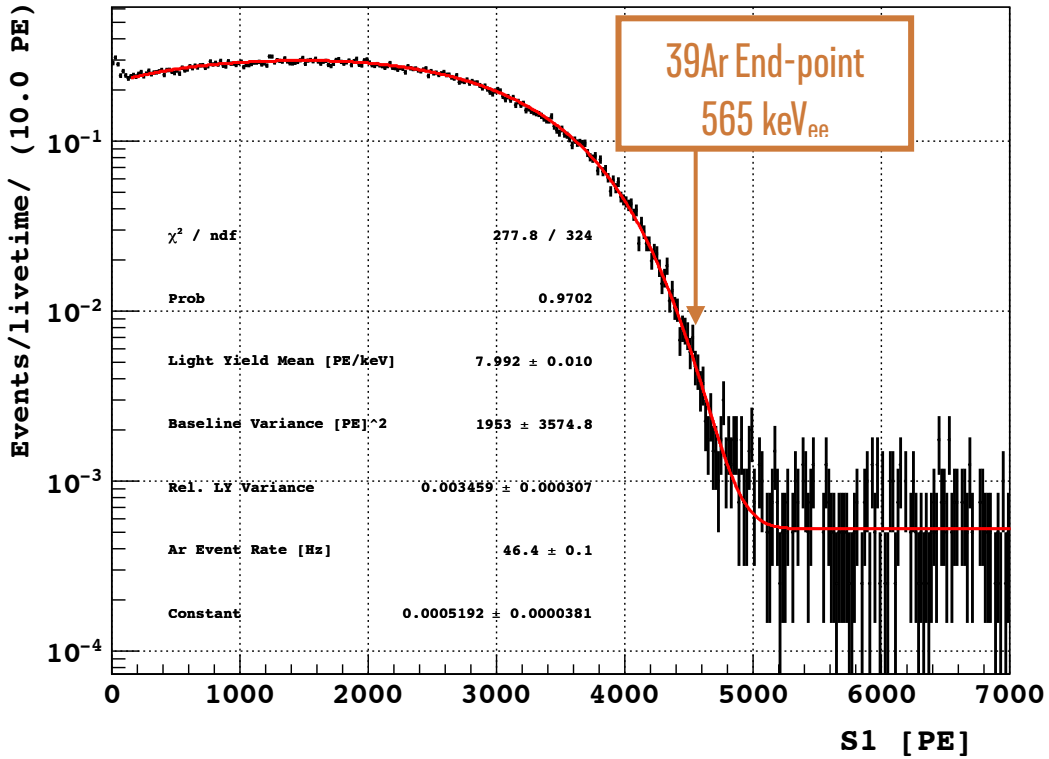
- Light Yield: liquid scintillator VETO LY of about 0.5 PE/keV$_{ee}$, satisfactory for VETO requirements.

- RATE: The background studies in the LS VETO evidenced a high rate due to ^{14}C.
  - *Identified the ^{14}C is from TMB (^{14}C content measured last week at LLNL via accelerator mass spectroscopy);*
  - *Identified and assayed a new batch of TMB with low ^{14}C content;*
  - *Test of TMB removal process to begin next week.*



TPC: ER calibration @ null field

The scintillation light yield is a critical parameter for argon detectors exploiting PSD. Photoelectron statistics can limit the rejection of electron recoils.



- Background run
- Dominated by 39Ar decays (46.4 Hz)
- Uniformly diffused in the volume

Found to be higher than what was assumed in the past for DS-50 PSD extrapolations.

^{39}Ar

AVERAGE LIGHT YIELD: 8.040 ± 0.006 (stat) PE/keV$_{ee}$
(systematic errors still under evaluation)

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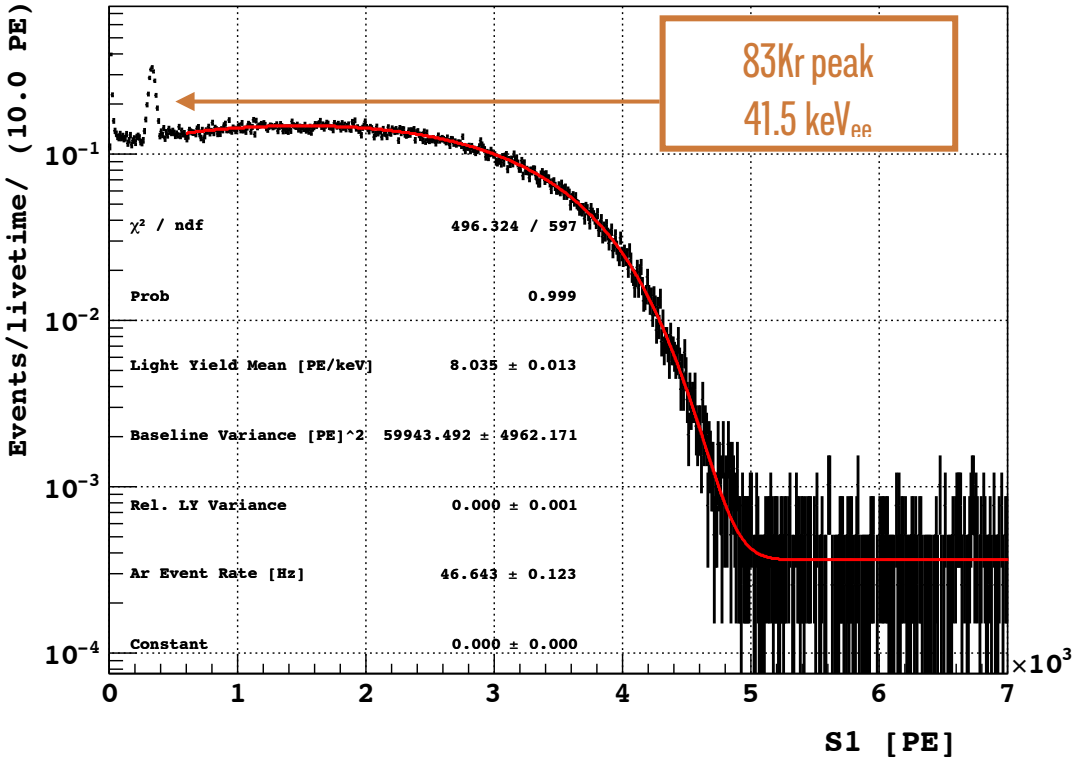
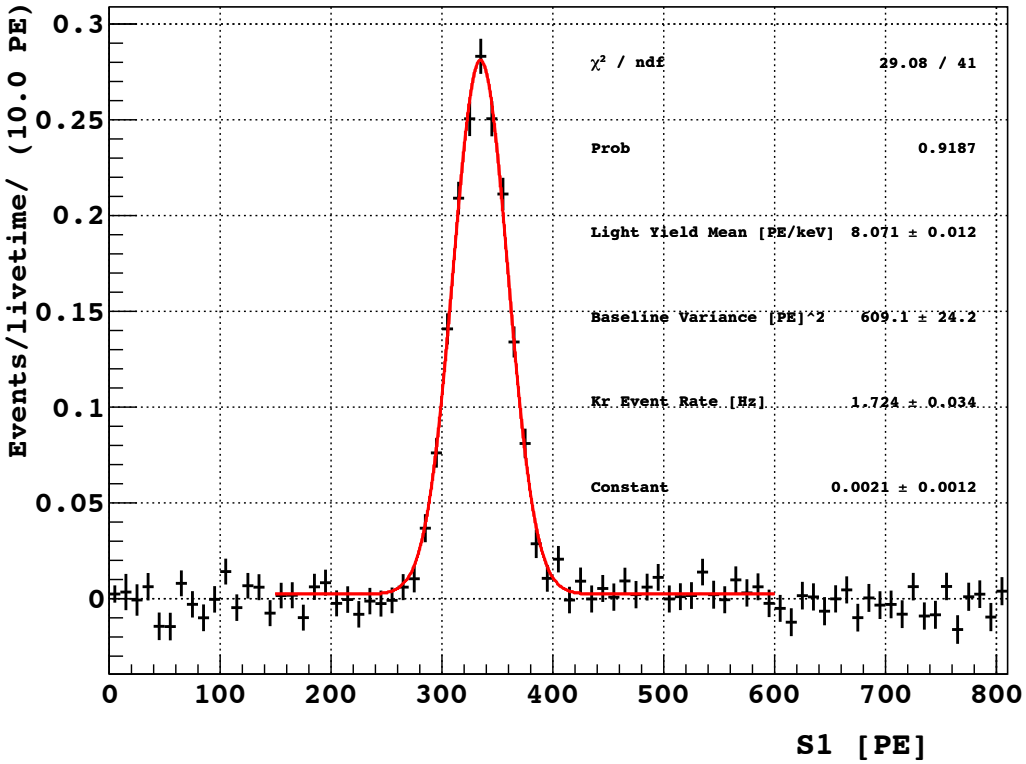


- Injected gaseous ^{83m}Kr
- Two sequential decays producing IC electrons, gammas or x-ray (154 ns).
- Total energy 41.5 keV$_{ee}$
- Half-life = 1.83 hours

^{83m}Kr

TPC: ER calibration @ null field

The scintillation light yield is a critical parameter for argon detectors exploiting PSD. Photoelectron statistics can limit the rejection of electron recoils.



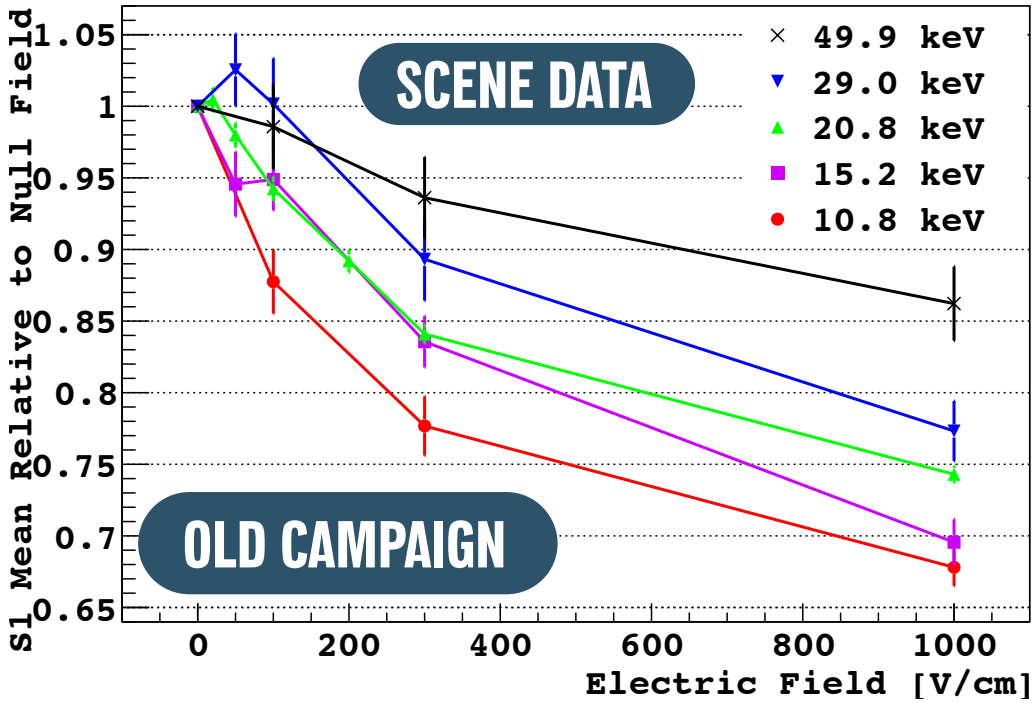
- Injected gaseous ^{83m}Kr
- Two sequential decays producing IC electrons, gammas or x-ray (154 ns).
- Total energy 41.5 keV$_{ee}$
- Half-life = 1.83 hours

Expected to be slightly higher since concentrated near the bottom of the TPC

^{83m}Kr

AVERAGE LIGHT YIELD: 8.071 ± 0.012 (stat) PE/keV$_{ee}$
(systematic errors still under evaluation)

TPC: NR calibration @ 200 V/cm



SCENE Project

SCintillation Efficiency of Noble Elements

Scintillation in LAr affected by electric field also for NR!

DS-50 now operating @ 200 V/cm

New SCENE Data *(presented by C.Cao on Friday)*

Measured NR scintillation efficiency in LAr

Data used in DS-50 projected sensitivity

- Need to study the response of the TPC to single nuclear recoils (expected from WIMPs);
- Neutron calibration in large detectors can be affected by multiple interactions of neutrons (normally accounted by means of detailed Montecarlo and a series of assumptions);
- SCENE has collected extremely pure samples of single nuclear recoils in a small TPC resembling DS-50 TPC design. We opted to use SCENE data @ 200V/cm, which we have access to. We have extrapolated the quantities of interest to the present analysis and, equally important, the associated systematics.

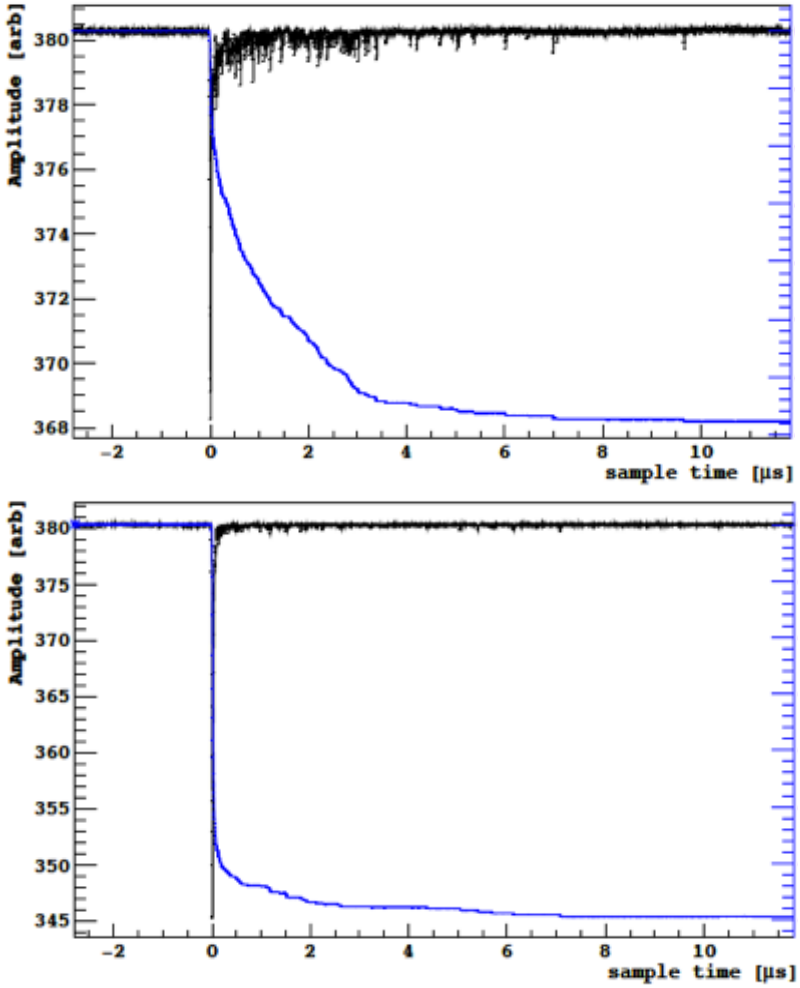
Pulse Shape Discrimination: F90

Primary scintillation is argon passes through the formation of Ar_2^* dimers that can be formed as singlet (6ns) or triplet (1.5 us). The relative population of singlet and triplet is strongly correlated with ionisation density and hence is function of energy, nature of the particle and field.

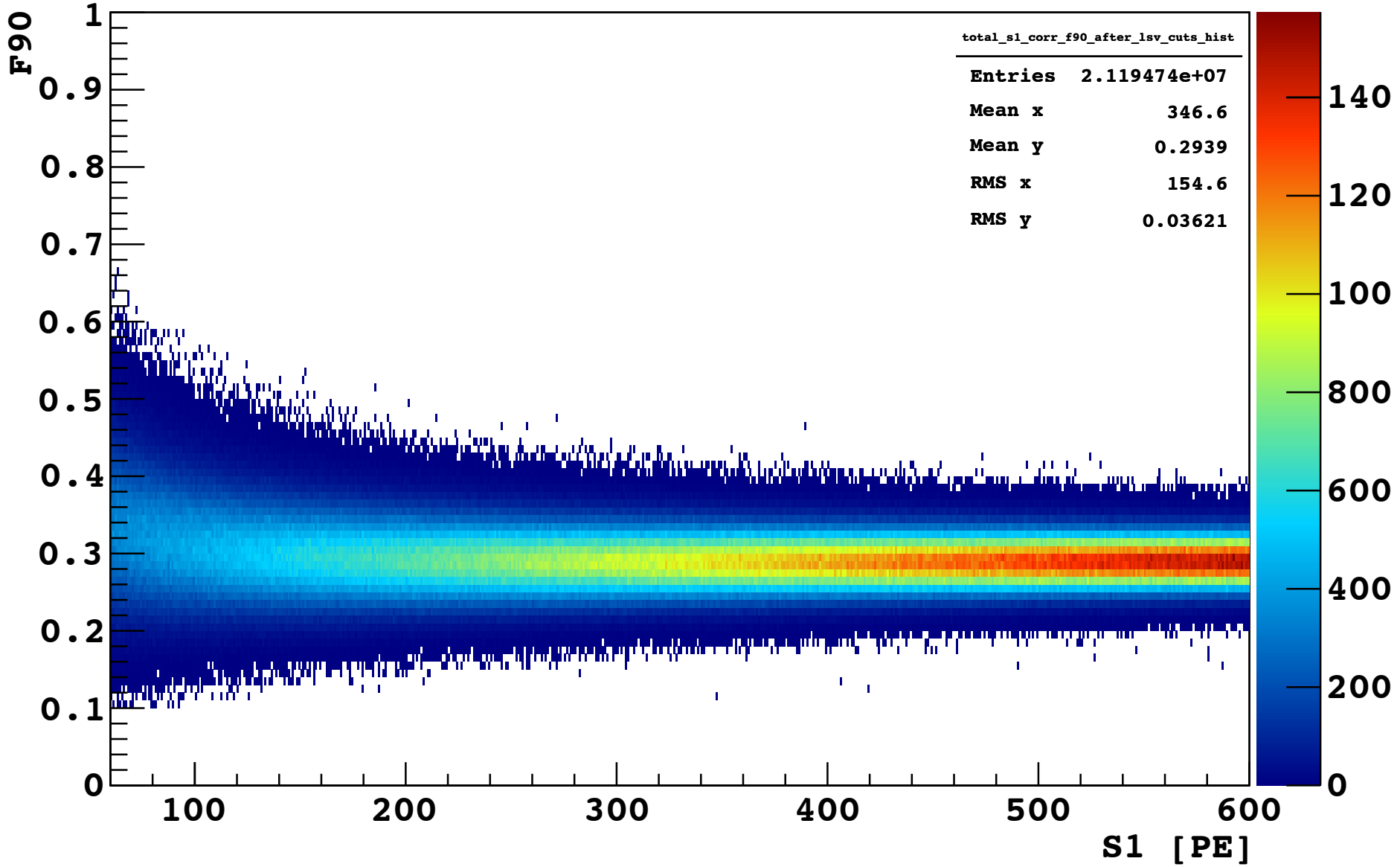
The PSD parameter F90 is defined as the fraction of scintillation light detected in the first 90 ns.

High energy ER
typical F90 ~ 0.3

NR
typical F90 ~ 0.7

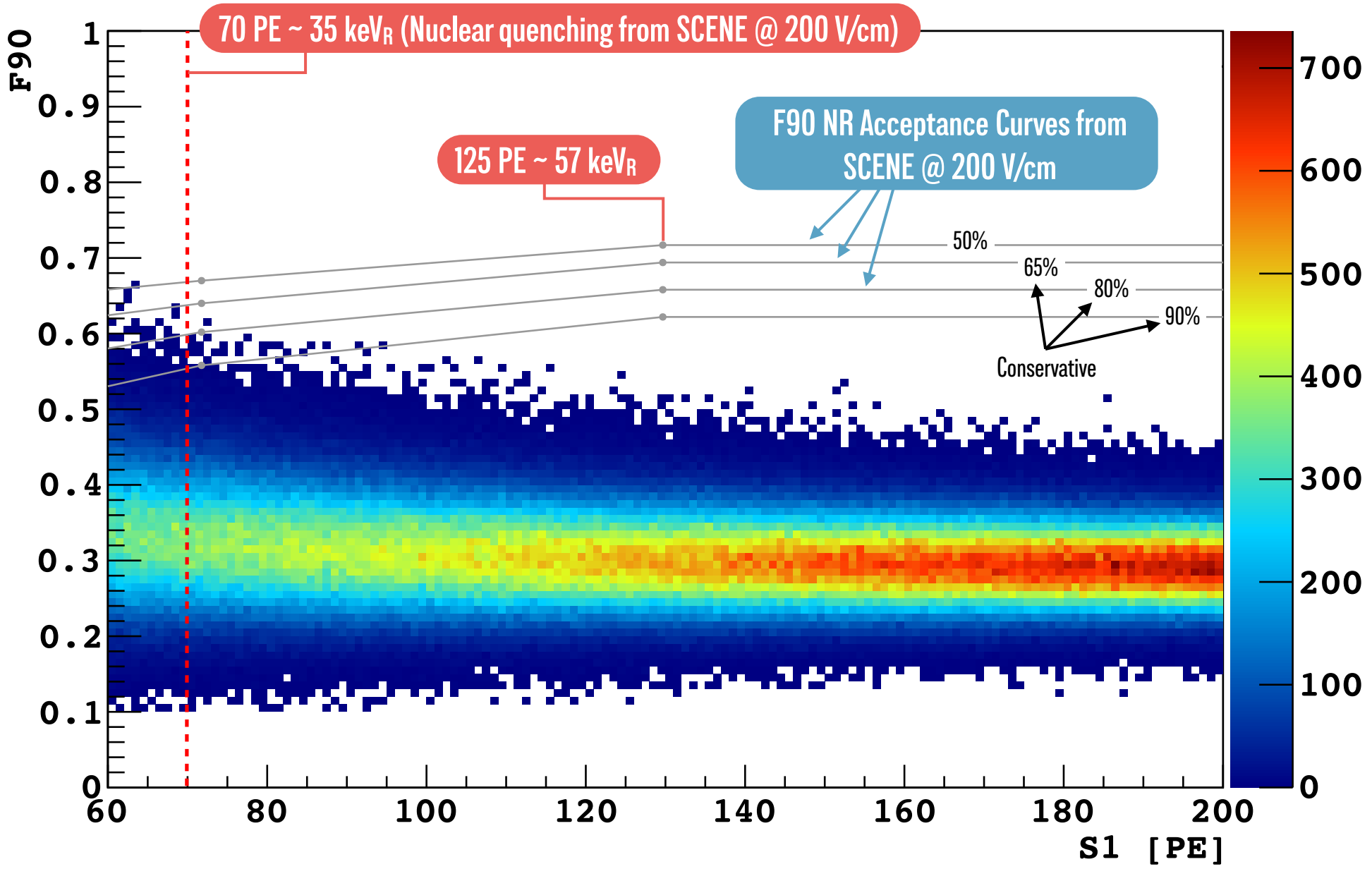


Background free exposure of 280 kg - day



Selected only single-hit interactions in the TPC fiducial volume (44.1 kg) with no energy deposition in the veto

Background free exposure of 280 kg - day



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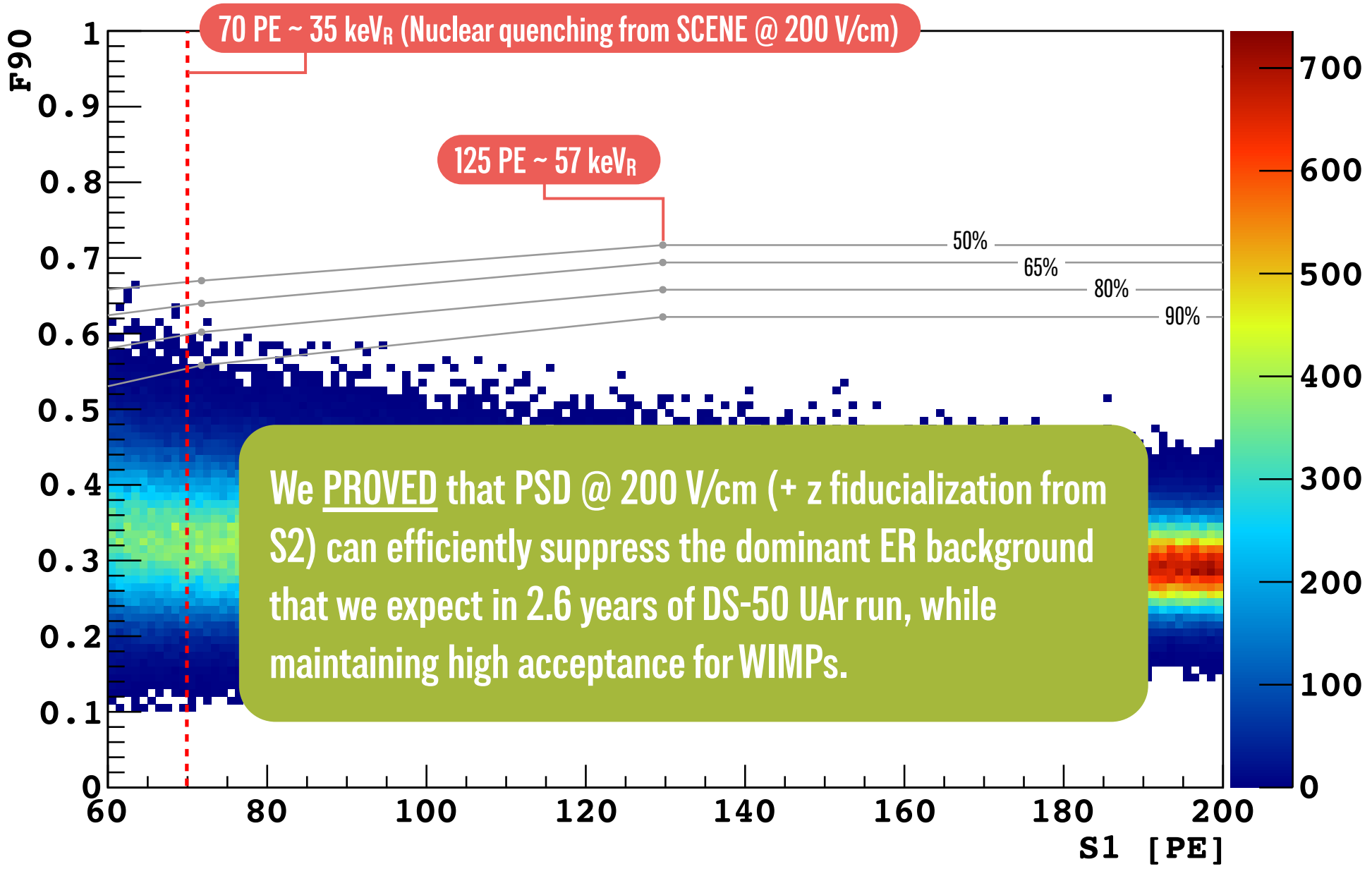

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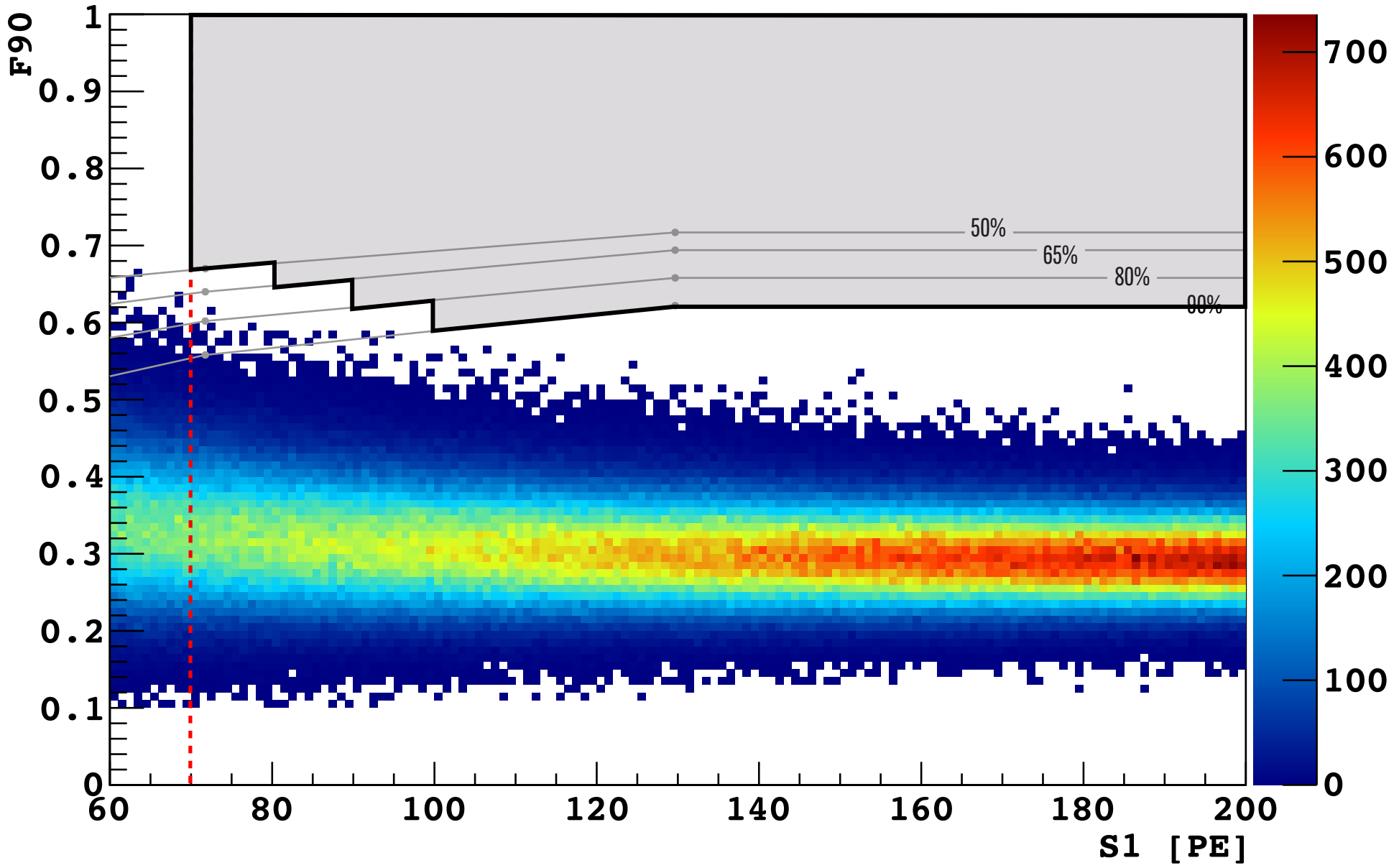
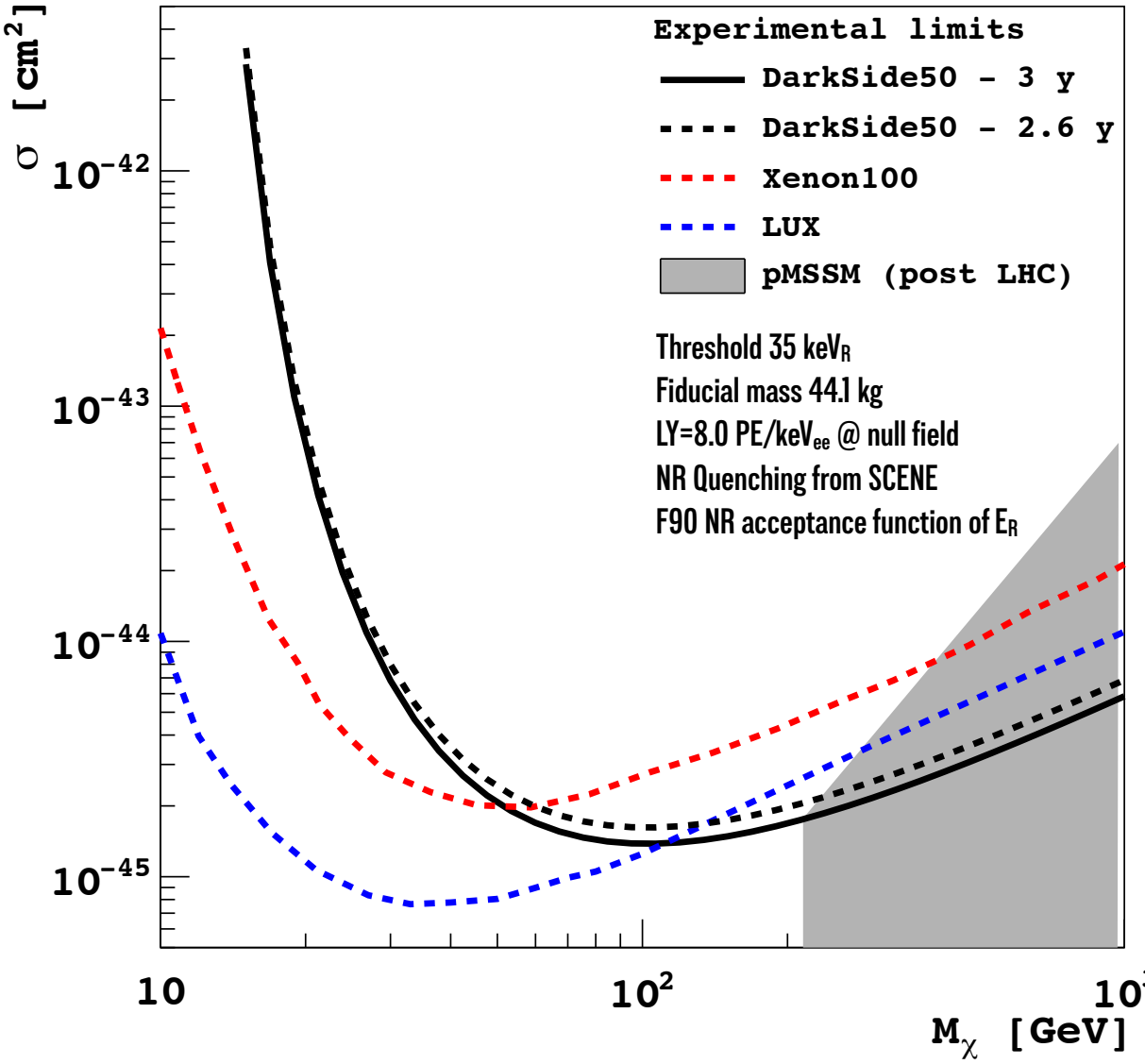


DS-50 projected sensitivity (90% C.L.)



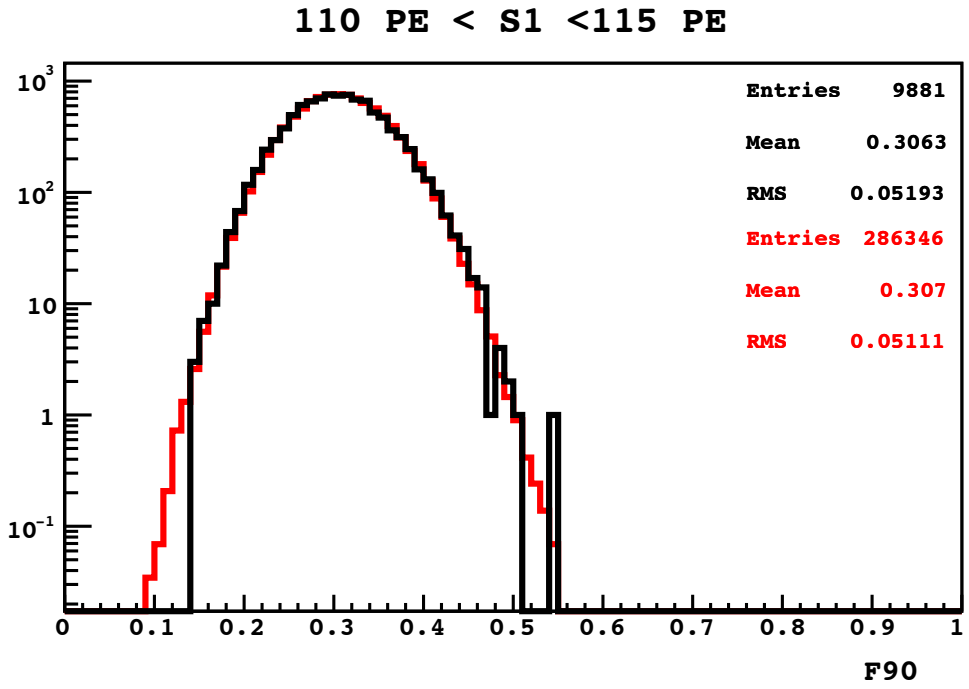
Projected sensitivity evaluated assuming:

- the measured PSD performance;
- no rejection from S2/S1;
- fiducialization along z axis-only;
- zero neutron-induced events;
- NR quenching and F90 acceptance curves from SCENE @ 200V/cm

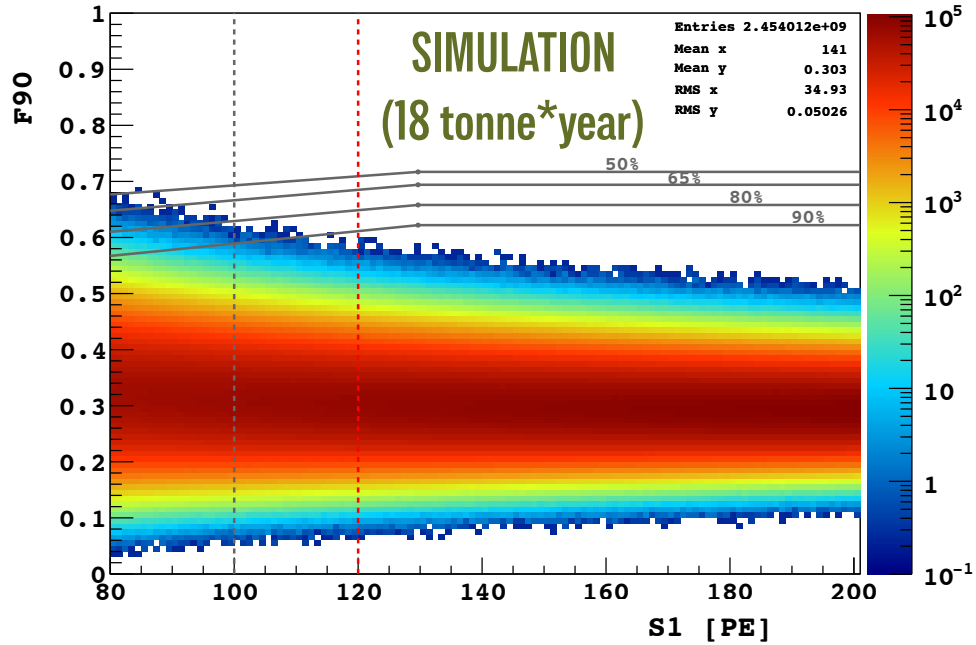
Present systematics on NR Quenching and F90 NR acceptance curves cause a ~10% variation of the projected sensitivity around 100 GeV/c^2.

PSD Model for DS-G2 extrapolation

Model the statistical properties of the F90 discrimination parameter using statistical distributions of the underlying processes with parameters taken from data. The model accounts for macroscopic effects related to argon micro-physics, detector properties and reconstruction and noise effects.

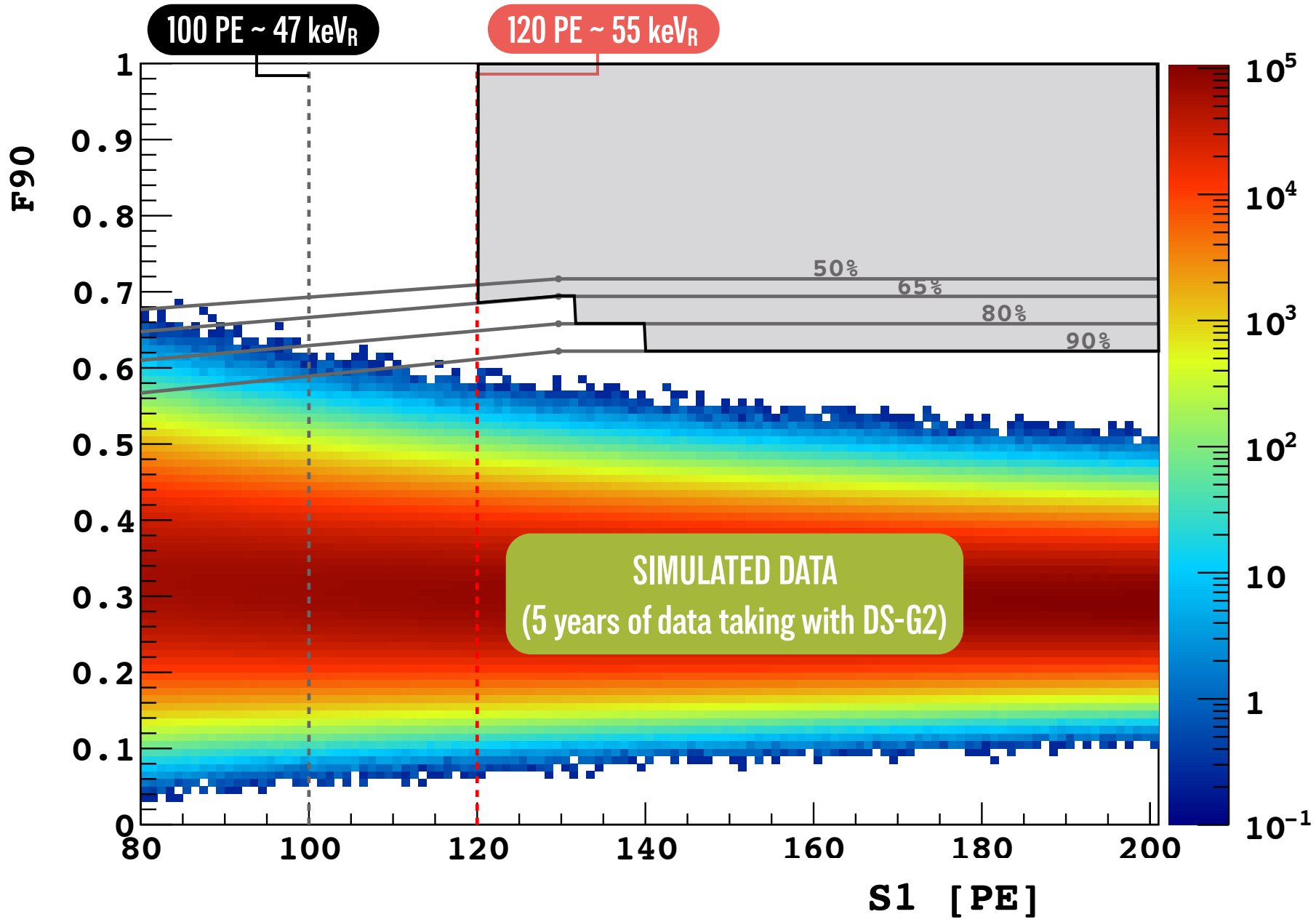


Excellent agreement through several orders of magnitude

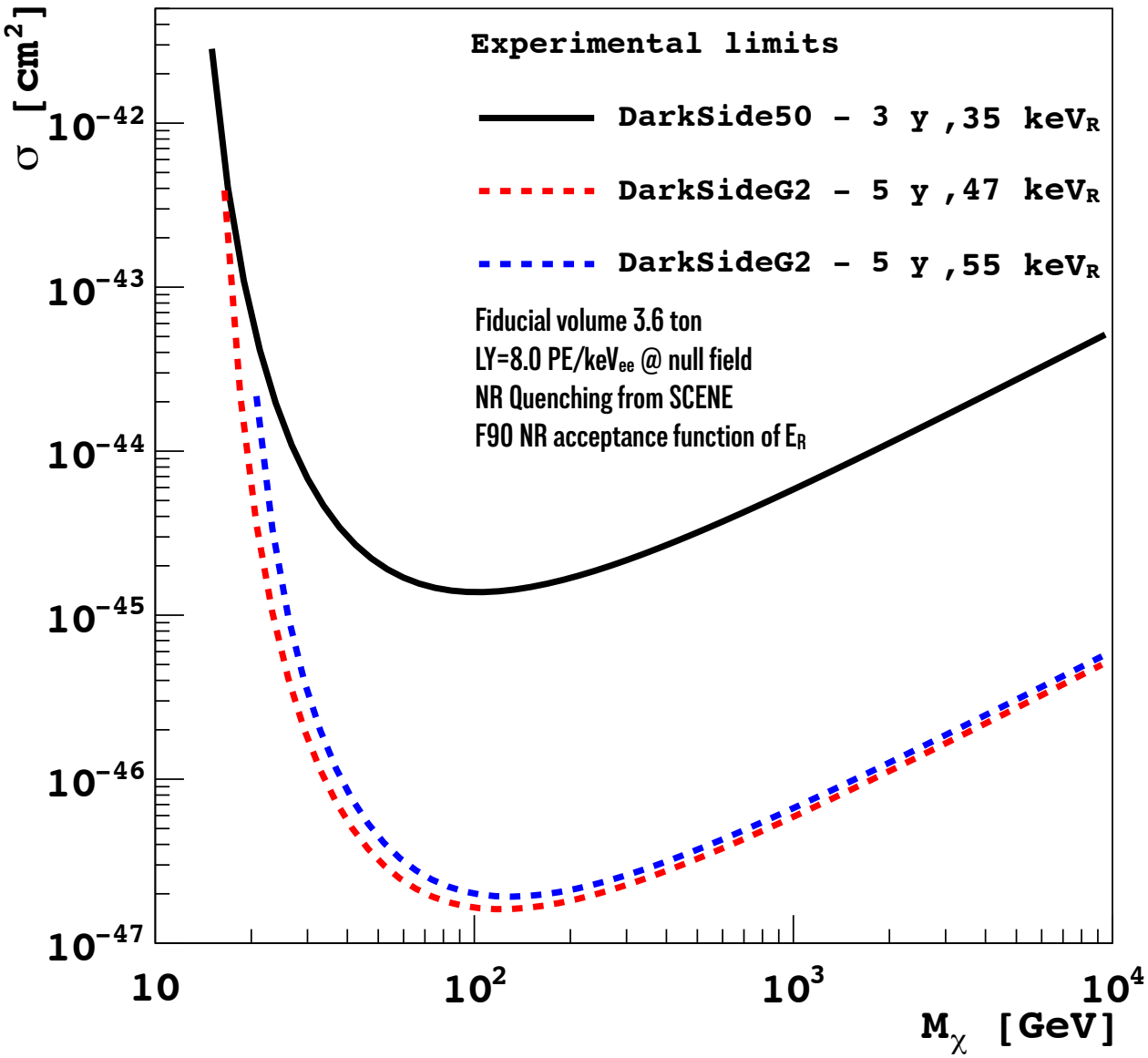


Simulated F90 distribution for DS-G2 5 years run, assuming the ER background in the fiducial volume will be dominated by ^{39}Ar @ its present upper limit.

PSD Model for DS-G2 extrapolation



DS-G2 projected sensitivity (90% C.L.)



Assumed:

- Same LY as in DS-50;
- PSD as per F90 model based on DS-50;
- no rejection from S2/S1;
- fiducialization along z axis-only;
- NR quenching and F90 acceptance curves from SCENE @ 200V/cm
- zero neutron-induced events according to present background MC study;

DArKSIDE-50

- DS-50 detector is running @ LNGS since Oct. 13;
  - *LAr TPC successfully commissioned;*
  - *Vetoes (designed to host DS-G2) successfully commissioned;*
  - *Scheduled to use Borexino distillation plant to separate PC from TMB and insert the new TMB with low ^{14}C content ;*
- Demonstrated PSD performance needed to reject the expected background from ^{39}Ar (at the level of present upper limit) in 2.6 years of DS-50;
- Plan to calibrate DS-50 and to further study PSD until June when we will switch to UAr and to WIMP search mode;
- DS-50 results extrapolated conservatively to DS-G2 indicate the possibility of running for 5 years ^{39}Ar-free.